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ABSTRACT

Web-based instruction provides a new medium for the presentation of instructional activities. The medium has the capability of addressing individual preferences and styles of learning through its structure and the use of multiple forms of media. Through careful design and adherence to the objectives of instruction and to learners' needs, Web-based instruction can provide a successful environment for a variety of learners. Factors in the Web-based environment, such as visualization, as well as individual student characteristics, such as goal orientation, achievement, and perception, must be taken into account so that the design of Web-based instruction enhances the educational opportunities of the learners. This study examines learner characteristics that impact engineering students' use of a Web-based instructional environment as well as their achievement. (Contains 17 references.) (Author/MES)

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Abstract: Web-based instruction provides a new medium for the presentation of instructional activities. The medium has the capability of addressing individual preferences and styles of learning through its structure and the use of multiple forms of media. Through careful design and adherence to the objectives of instruction and to learners' needs, web-based instruction can provide a successful environment for a variety of learners. Factors in the web-based environment, such as visualization, as well as individual student characteristics, such as goal orientation, achievement, and perception, must be taken into account, so the design of web-based instruction enhances the educational opportunities of the learners. This study examines learner characteristics that impact engineering students' use of a web-based instructional environment as well as their achievement.

Research Framework

Web-based instruction is a form of hypermedia that is delivered through the World Wide Web [WWW]. Web-based instruction provides a new medium for the presentation of instructional activities that has the capability of addressing individual preferences and styles of learning through its structure and the use of multiple forms of media. Web-based instruction can be developed to closely augment the structure of a learner's memory and place the learner in control of instruction. In the development of web-based instruction, the designer must realize that the instructional media are merely vehicles for the exchange of ideas. There is a need for sound pedagogy and meaningful and stimulating learning experiences that focus on the needs of the learner in order to improve education (Reeves, 1996). The understanding of principles about how individual learners organize and retrieve knowledge and develop personal schema is vital to the design of web-based instruction.

Due to the shift from behavioral to cognitive perspectives, researchers have become increasingly interested in the manner in which learners process information (Ausburn & Ausburn, 1978). Cognitivists define education as not the mere transmission of facts, but the construction of robust mental models (Ormrod, 1995). As a cognitive tool, the WWW can be utilized for knowledge construction instead of reproduction, the design of knowledge, and meaningful learning (Reeves, 1996). Therefore, it is important to determine how individuals learn in order to determine how web-based instruction can reach its potential in educational settings.

The designers of web-based instruction can capitalize on its characteristics as a form of hypermedia instruction to meet the needs of individual learners. First of all, the environment can be designed to take advantage of the structure of the learners' mind. Web-based instruction is a potential learning tool with the capability for extending and augmenting the mind of a learner (Marmolin, 1991). The environment can serve as an information processor, guiding or scaffolding students through cognitive strategies to enhance the organization of their knowledge structures. Web-based instruction has the capability to move the act of learning from hearing and seeing to doing and understanding. Secondly, web-based instruction can capitalize on a learner's motivation for learning, the individual's goal orientation, and their verbal or visual learning preference. By adapting to individual learning styles during the design phase of web-based instruction, individual needs in the learning situation are met.

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In order to aid students in the visualization of information, web-based instruction can be designed using multiple forms of media, such as animations, graphics, and text. These multiple forms of media provide the learners with rich and realistic contexts for multichannel learning. The navigational scheme of the environment can be designed so the interface is user-friendly, simple, and the interconnectedness of ideas is clear (Cockburn & Jones, 1996; McLellan, 1992). Learners' goal orientation, whether task goal orientation, relative ability orientation (performance-approach or performance-avoid), or extrinsic goal orientation, affects the learners' focus while exploring the information provided in the environment. These classifications impact the students' performance in the class and their navigational pattern within the environment. Finally, students' perceptions of web-based instruction ultimately impact its value and use.

In web-based instruction, the design should not be transferred just from one medium to another, but the experience should be redefined with the capabilities of the new medium utilized. Instructional designers must capitalize on the new opportunities that the web provides to learners--to access information from remote locations, to interact with the instruction, to access the instruction at their own pace, to visualize the instruction, and to see the complex relationships in the instruction (Alexander, 1995; Owston, 1997). The design of web-based instruction should not focus on the technology but on the goals of the lesson, the needs of the learner, and the nature of the task involved (Rieber, 1994). "The World Wide Web can appropriately be considered the largest and most diverse hypermedia system in existence" (Eveland & Dunwoody, 1998); however, little research has been published regarding the uses and effects of learning from a web-based environment. Therefore, there is a need for more sound research about the impact of the WWW on learning.

Research Questions

In order to validate the design and utilization of a web-based instructional environment such as *ThermoNet*, several research questions were explored. These questions focused on the design features that best enable students of thermodynamics to succeed in a web-based instructional environment. The questions this study attempted to answer were: (1) Which student characteristics affect student achievement to the greatest degree? Characteristics to consider are students' goal orientation, modal learning preference, and access time., (2) Which student characteristics affect the amount of time students engage in *ThermoNet* to the greatest degree? Characteristics to consider are students' goal orientation and modal learning preference. Additionally, how does students' academic achievement affect the amount of time students engage in *ThermoNet*?, (3) How are students' perceptions of *ThermoNet* affected by their characteristics? Characteristics to consider are students' goal orientation, modal learning preference, access time, and achievement., (4) What are the benefits of utilizing the web both as an instructional and a research medium?

Design of Study

Sample

The participants of the study (113) were volunteers taking the course ME 326: Thermodynamics in the School of Engineering at the University of Texas at Austin. The course is an introductory level course based on thermodynamics that is required for all engineering majors who are focusing on mechanical engineering; therefore, students within the course had a wide range of abilities. Typical of engineering courses, there was a male dominance with only 17% of the population consisting of females. The average age of a student enrolled in the course was 21.2 with ages ranging from 18-35. The breakdown of the ethnic background of the students included: 45% Anglo-Saxon, 28% Asian, 12% Hispanic, and 6% African-American. The remaining 9% chose not to disclose their ethnic background.

The amount of computer access and expertise for the sample population was plentiful. Out of the students polled, 82% of the students had computers at home while 18% did not. A large percentage of the students (38%) had also used advanced applications, such as programming and web publishing. The majority of students felt that they were fairly competent in using computers.

Treatment

The web-based instructional site used for the study is entitled *ThermoNet*. The underlying goal of *ThermoNet* was to be the most versatile and interactive source of thermodynamics on the Internet. Since the time of its creation, *ThermoNet* has evolved into a more comprehensive source of information to supplement regular classroom instruction for the course ME 326: Thermodynamics.

Due to the potential benefits of a web-based instructional environment, it was deemed unethical to pursue research with a group of students who had no access or less than desirable access to the treatment condition; therefore, *ThermoNet* was accessible by all of the students involved in the study, and no control group was used. Since *ThermoNet* was conceptualized as a supplement to traditional classroom instruction, groups of students who utilized the web site to varying degrees naturally occurred.

ThermoNet was designed as an instructional web site for many reasons. It was originally envisioned as a site for students to not only find supplementary materials to the textbook, but also to particularly focus on the elements of communication that utilize the unique attributes of the web. Those elements of communication included the use of graphics, interactivity, access to subject matter, and access to real-world applications. The goal of the developers was to create a highly graphic site since thermodynamics is not a naturally graphic topic. The developers used interactivity as a key component of *ThermoNet*. The objective was to present concepts succinctly and then enable the student to interact with the web site to reinforce the concept. Finally, the developers created real-world applications within *ThermoNet*. Through graphics and video clips, more real-world applications could be portrayed in an instructional web site than in a conventional text. In summary, the developers attempted to capitalize on material that could be communicated through the web and was not readily accessible by a student of thermodynamics.

Variables

Independent Variables

There are four independent variables used in the study: (1) goal orientation, (2) verbalizer-visualizer classification, (3) academic achievement, and (4) access time. Students' goal orientation was measured by an adaptation of the Patterns of Adaptive Learning Survey (PALS, Midgley et al., 1997). PALS was designed to measure four separate constructs: task goal orientation, performance-approach goal orientation, performance-avoid goal orientation, and extrinsic goal orientation. The Cronbach's alphas for this scale were reported from .69 to .76 (Midgley et al., 1997) and greater than .70 (Midgley et al., 1998). The students were classified as either a verbalizer or visualizer according to the Verbalizer-Visualizer Questionnaire [VVQ] (Richardson, 1977). The VVQ was found to have adequate internal consistency reliability, .70 and .59 for verbal and visual items respectively (Kirby et al., 1988). Students' knowledge about the concepts of *ThermoNet* was assessed through a posttest. The posttest was the students' final exam that was developed by the professors participating in the study. Students' access time was calculated by subtracting the time students entered *ThermoNet* from the time they exited the site. The server tracked the students' usage for two months--from mid-semester until the end of the semester.

Dependent Variables

There are three dependent variables used in the study: (1) academic achievement, (2) access time, and (3) perception of *ThermoNet*. Both academic achievement and access time were briefly described in the *Independent Variables* section. In order to determine the utility of *ThermoNet* and the impact of a web-based instructional environment on students, a Perception Survey was given to the subjects in the study. The content of the survey covered the following categories: Achievement and Design. The coefficient alphas for the Perception Survey subcategories were .91 for the achievement category and .89 for the design category with an overall alpha of .92.

Qualitative Data

Each student who participated in the study filled out a detailed questionnaire. This questionnaire was solicited in order to gain further information regarding the students' perceptions regarding learning thermodynamics and their perception of the potential usefulness of computer-based learning resources. In order to get further insights into the general use and evaluation of *ThermoNet*, qualitative interviews were administered to individuals in the study. Interviewees were a diverse selection from the sample population. Students were selected for the interviews using purposeful sampling: theory based sampling and maximum variation sampling (Patton, 1990). The purpose of the interview was to probe the reasons behind students' time spent engaged in *ThermoNet*, their preferred learning style, their favorite features of *ThermoNet*, and what aspects of *ThermoNet* they believed could be enhanced in the future.

Procedures and Analysis

Each of the 3 classes of *Thermodynamics* was asked to participate in the study. Prior to conducting the study, the contents and features of *ThermoNet* were demonstrated to students in their discussion groups. Because the web-based instructional environment was a supplement to the students' typical instruction, the subjects accessed the site during their personal study time. The time that students used *ThermoNet* was a unique aspect of the study since the data were gathered from the server. The demographic questionnaire, Perception Survey, VVQ, and adaptation of the PALS were administered during discussion groups that were conducted by the teaching assistants. The academic achievement test was administered during the regular final exam time by the professor of the course.

In order to answer research question one (Which student characteristics affect student achievement to the greatest degree? Characteristics to consider are students' goal orientation, modal learning preference, and access time.), a stepwise regression was calculated to determine if student characteristics and access time predicted the academic achievement. All of the students who participated in the study, whether or not they actually accessed *ThermoNet*, were included in the regression analysis. All of the students were used since insight could be gained from knowing whether or not students of certain characteristics accessed the site or not.

In order to answer research question two, (Which student characteristics affect the amount of time students engage in *ThermoNet* to the greatest degree? Characteristics to consider are students' goal orientation and modal learning preference. Additionally, how does students' academic achievement affect the amount of time students engage in *ThermoNet*?), a stepwise regression and an ANOVA were performed. First, the regression was used to determine if student characteristics predict access time. All of the students who participated in the study, whether or not they actually accessed *ThermoNet*, were used in the regression analysis. Second, an ANOVA test comparing the access time among two achievement groups was conducted. The top and bottom quarter in terms of achievement, was the independent variable.

In order to answer research question three (How are students' perception of *ThermoNet* affected by their characteristics? Characteristics to consider are students' goal orientation, modal learning preference, access time, and achievement.), a stepwise regression was calculated to determine how the student characteristics, access time, and achievement predicted the students' perception of *ThermoNet*.

In order to answer research question four (What are the students' perceptions of the benefits of utilizing the web both as an instructional and a research medium?), questionnaires were administered to all of the students and open-ended interviews were conducted with students of differing achievement levels and with students labeled as visualizers and verbalizers to gain insight into the students' backgrounds and perceptions of *ThermoNet*.

The ultimate goal in analyzing the preceding research questions was to determine the impact of learner characteristics on students' achievement in thermodynamics and their perception of a web-based instructional environment. With this goal in mind as well as the limitations of the study, the quantitative questions were analyzed using the statistical procedures, regression analysis and ANOVA. The results of these statistical analyses were triangulated with the qualitative interview data.

Results and Discussion

The present study gives many insights into the students' characteristics, and how these characteristics impact the students' achievement, their use of *ThermoNet*, and their perceptions of a web-based instructional environment. While some of these results seem counterintuitive, they reveal how specific student characteristics need to be taken into account during the design and development of web-based instruction.

One of the main goals of the study was to determine the effect of students' goal orientation, learning preference, and access time on their achievement. The stepwise regression analysis showed that the best predictors of achievement were performance-avoid goal orientation ($t=-2.976$, $p<.05$) and performance-approach goal orientation ($t=2.293$, $p<.05$). These two variables predicted almost 11% of the variance in the students' final exam grades. Students with a performance-avoid goal orientation were more likely to have a lower achievement level. On the other hand, students with a performance-approach goal orientation were more likely to have a higher achievement level. Students with a performance-approach goal orientation focus on demonstrating and proving competence. They tend to be competitive in a scholastic setting and this competition often leads to the acquisition of a higher achievement level. On the other hand, students with a performance-avoid goal orientation tend to be low achievers. Typically focused on avoiding the display of lack of competence, these students tend to feign more intellectual ability than they actually possess. They often try to avoid challenging tasks and display decreased performance (Elliott & Dweck, 1988; Miller et al, 1993).

The results suggest that the web-based instructional environment had no impact on the students' achievement since time spent engaged in *ThermoNet* was not a predictor of achievement. In order to gain additional information about achievement, students who did log on to *ThermoNet* were divided into two groups according to the amount of time spent on *ThermoNet*. Table 1 reveals the descriptive statistics for the two groups of individuals who used *ThermoNet*. The descriptive statistics revealed that students who used *ThermoNet* less actually had a higher achievement score than students who used *ThermoNet* for more than 90 minutes. Therefore, an analysis of variance for the two groups was conducted which revealed that the difference between the two groups was not statistically significant although the large difference in number of students in each group was a limitation.

Variable	Mean	SD	Minimum	Maximum	N
Group 1 (1<Time< 69)	50.63	13.20	15.5	74.5	42
Group 2 (90<Time<556)	43.15	14.16	7.0	63.5	13

Table 1: Descriptive Statistics of Achievement Scores by Access Time

In order to determine the effect of student characteristics on students' access time, it was necessary to determine which of the variables had a significant relationship with the amount of time spent engaged in *ThermoNet*. None of the variables attained the .05 level of significance needed to be entered into the regression equation. In other words, none of the student characteristics of goal orientation or learner preference predicted access time. However, out of 113 students who had access to *ThermoNet* as a supplement to their instruction, 58 students did not access the web site and only 13 of the students accessed *ThermoNet* over one and one-half hours. This lack of engagement in the instructional medium impacted the results of the study.

Since the variables were not significant predictors of time, an ANOVA was conducted to determine if there was a significant difference between two achievement level groups (low and high) with respect to the time they spent engaged in *ThermoNet*. The analysis of variance showed a significant difference between the achievement groups for the amount of time students spent on *ThermoNet* ($F=4.285$, $p<.05$) with the low achievement group spending more time accessing *ThermoNet* (see Table 2). However, the small number of students in each group was a limitation. This finding supports the prior finding that students who spent more time accessing *ThermoNet* had a lower achievement level.

ANOVA	Sum of Squares	F	Mean Square	F	Sig of F
Main Effects Quarter	6918.376	1	6918.376	4.285	.049*
Residual	38749.934	24	60.4		
Total	45668.309	25	1826.732		

*significant at the .05 level

Table 2: Access time ANOVA's Result

The way students perceive an instructional medium impacts the way they interact with it and how it affects their achievement. In order to determine how students' perceptions of *ThermoNet* impacted their achievement, a stepwise regression analysis was computed. The regression analysis showed that the best predictors of students' perception of *ThermoNet*'s impact on achievement were performance-avoid goal orientation ($t=3.655$, $p<.05$) and extrinsic goal orientation ($t=-2.622$, $p<.05$). These two classifications predicted almost 27% of the variance in the students' perception.

A regression analysis was also conducted to determine the predictors of students' perceptions on the design of *ThermoNet*. The regression analysis showed that the best predictors of students' perception of *ThermoNet*'s impact on achievement was the final exam grade, verbalizer, and performance-avoid goal orientation. These three classifications predicted over 27% of the variance in the design portion of the *ThermoNet* Perception Survey.

The results of the questionnaire indicated that students often have difficulty applying general theory to specific cases and formulating solutions from problem descriptions. They also insinuated having difficulty knowing where to find correct property data for example problems. Students suggested they were lacking a physical "feel" for the subject matter. Overall, the students implied that they were satisfied with the course. They were content with the

depth of knowledge, the time spent on specific sections of the course, and the tests covering the information. In order to extend the information gathered through the instruments specified in the study, eleven students voluntarily participated in an interview. Several themes emerged from the analysis of the interviews. These themes included: lack of time, focus of content, preferred mode of learning, and future enhancements.

Many developers believe that when they develop effective instruction, adoption of its use will follow in time; however, this might be a false assumption. The "if you build it, they will come" mentality is not a true statement when working with students who are already pressed for time and are given the option of whether or not to use the instructional medium. Present day students grew up using video games and have a "point-and-click" mentality. This is a trend and designers must tailor their approach to designing instruction to fit the natural background of the students. Therefore, in order to have students access a web-based instructional environment, incentives or requirements must be built into the design. These incentives should be determined during the outset of the development of the site so that the objectives of the web-based instruction can be designed around this idea. Otherwise, if there is no required connection between the web-based environment and what students are expected to learn, there will be little traffic on the site as was evident in this study.

Although the effectiveness of web-based instruction is still unknown for the majority of contexts, the present study attempted to find some research evidence for the support of web-based instruction. The findings of this study provide insight into the type of individuals who use and benefit from web-based instruction and how these characteristics predict their perceptions of a web-based instructional environment. While some of the findings were inconsistent with hypothesized results, the study as a whole gives insight to instructional designers about the capabilities of the WWW for instruction and how web-based instruction should be designed to promote learning.

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